Irradiation Test of NITE-SiC/SiC Fuel Claddings with Fuelled Segments in HBWR, Halden

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Abstract
After the March 11 Disaster in East-Japan ensuring safe technology for LWR becomes a top priority R & D in nuclear energy policy of Japan. The role of the high temperature non-metallic materials is becoming more important for the advanced nuclear reactor systems. SiC fiber reinforced SiC composite has been recognized to be one of the most attractive options for nuclear systems. METI fund based projects, named INSPIRE (Innovative SiC Fuel-Pin Research) has been launched as 5 year termed projects at OASIS, Muroran Institute of Technology. This project aims to replace Zircaloy claddings to SiC/SiC based materials, where in-reactor neutron irradiation of SiC/SiC fuel claddings with fuel pellets is a major task. To fabricate 200mm long NITE-SiC/SiC tubes to satisfy ASTM standard for Zircaloy fuel cladding is under progress with satisfying the major requirements. The SiC/SiC claddings to be irradiated in HBWR next year are reaching the final stage and those will be jointed both ends with Zircaloy tubes and will be delivered to Halden early next year.

Background of Project “INSPIRE”

BACKGROUND OF PROJECTS “INSPIRE”

Based on the “Basic Energy Policy” (June, 2010) and reflecting the after effects of East Japan Earthquake (March 11, 2011), the 4th Phase Basic Plan of Science and Technology (Aug, 2011) was issued. The Revised Version of “Framework of Nuclear Energy Policy for 2012” had been prepared, but was cancelled on October 2, 2012, where the followings were emphasized.
- Restructuring of nuclear energy policy towards safety assurance and recovery of public trust.
- Restructuring of nuclear energy policy under large drop of energy dependence on nuclear.
- Establishment of “The Highest Level of Nuclear Safety” is strictly required.

R & D TARGET AND CURRENT STATUS TOWARD 2017 MARCH

Baseline Concept:
Replaceable SiC/SiC cladding from Zircaloy cladding is to be developed. Thus the specification is aimed to satisfy ASTM Standard B 315-07, which is for LWR application. Project “INSPIRE” is targeting to produce 10mm inner diameter, 1mm wall thickness and 200mm long claddings with sufficient gas tightness.

**Dimensional Accuracy:**
- Diameter: ±0.05mm
- Wall Thickness: ±0.10%
- Roundness: ±0.05mm (Accomplished)

Baseline Mechanical Properties:
- Axial Tensile Strength: 300MPa
- Hoop Strength: 100MPa
- Fracture at accident: no straight crystallographic through thickness fracture (+42.2% Pseudo-plasticity)
- Environmental Resistance:
  - Neutron Damage Resistance: 1) Densities check up to 10GWh at Halden Reactor under BWR water condition.
  - 2) Confirm mechanical property degradation less than 5% at BFG reactor irradiation.

SiC/SiC Pin + Zircaloy End Caps Joint

X-RAY CT IMAGES OF SiC/SiC AND ZIRCALOY JOINT

The Current Project Plan

The irradiation is to be conducted in a test rig within a pressure flask, cooled by water at BWR thermal-hydraulics and chemical conditions (see figure).
- The irradiation will accommodate 6 test rods, typically 20 cm long, arranged in two clusters, as shown in the figure on the right hand side. The rods will be equipped with cladding elongation detector for measuring on-line the amount of pellet-cladding mechanical interaction (PCM) and cladding permanent growth due to PCM and neutron irradiation.
- Test rods: The six rods may contain different variants, such as different cladding or end-plug material.
  - Fuel pellets will be fabricated at the IE establishment at Kjeller, under agreed specifications. The cladding tube and the end plugs will be provided by the customer, who is also to define, in consultation with Halden, the rod inner pressure. Currently, atmospheric pressure is foreseen. The fuel rod assembly, gas filling and end-plug welding will be realized by IE following further discussions and under agreed specifications.
  - In-reactor operation: It is foreseen that the test will be run at power conditions typical for commercial fuel, i.e. 20-25 kW/m at beginning of irradiation and then gradually decreasing. The PCM and permanent cladding strain will be assessed continuously during the irradiation.

Preliminary concept of the test rod for “INSPIRE” irradiation in Halden Reactor

- 6 rods/rig. 1 m of Zircaloy/ 1 m of un-fuelled SiC/SiC & 4 SiC/SiC rods with 2 material/fuel variants
- Open end SiC/SiC rods with Zircaloy end parts will be provided by MLIT.
- Fueling/end-cap joining by EBW will be done at by Halden R. P.